NEAR SURFACE PHENOMENA IN THE INHOMOGENEOUS COASTAL BOUNDARY LAYER

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LONG TERM GOALS

The long-term goals of the research are to understand and assess the effects of the atmosphere on the detection of targets at low altitudes over sea with LR-IRST systems. Effects considered are transmission losses due to aerosols and water vapor, effects of turbulent fluctuations of the air temperature on blurring and scintillation, and the effect of the vertical temperature gradients on IR refractivity.

OBJECTIVES

The objectives of the research performed in the framework of the present grant are:

- to describe the aerosol source function in coastal areas at short fetches;
- to quantify the effect of the surf zone on the production of sea spray aerosol;
- to determine the turbulence and refractivity in the inhomogeneous coastal boundary layer and their effects on imaging of low altitude point targets;
- to improve the description of the aerosol size distribution as function of height and meteorological parameters.

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APPROACH

Aerosol source function.

Aerosol particle size distributions are measured off the Californian coast during EOPACE (Electro-Optical Propagation Assessment in the Coastal Environment), when possible at several levels in the surface layer. The data will be analysed to determine the aerosol source function, which in turn will be described in terms of meteorological and wave parameters. In addition, data from a variety of other locations will be used in this effort to cover situations and conditions that are representative for 'typical' scenarios and thus allow for extrapolation of the results to other areas. When bubble size distributions are also available, an attempt will be made to discriminate between bubble-mediated production of aerosols and spume droplet production. An effort will be made to improve the proposed formulation for bubble-mediated jet droplet production [De Leeuw, 1990] in collaboration with Dr. Spiel (NPS,

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Monterey, CA). Dr. Spiels research has provided us with more accurate formulations for the parent bubble - daughter droplet relations for single bubbles [Spiel, 1994].

Surf-zone production of aerosols.
During the EOPACE Surf experiments in San Diego (Scripps Pier, La Jolla) and Monterey (Moss Landing Marine Institute) the production of aerosols in the surf zone is quantified from particle size distribution measurements upwind and downwind from the surf zone, if possible at different levels. Prior to these measurements, the optical particle counters used in these surf experiments are calibrated and intercompared, to avoid compatibility problems that are frequently observed between un-like instrumentation.

Turbulence and refractivity.
Optical turbulence and refractivity are due to different phenomena, i.e. turbulent fluctuations of the air temperature and variation of the mean air temperature with height. They are studied during the EOPACE IOP's. Visible and IR sources mounted on the pier in Moss Landing at different heights were monitored across Monterey Bay with camera systems in Monterey, providing an over-water path with a length of 22 km. Similar experiments were carried out across San Diego Bay over a 14 km path, with sources mounted on Imperial Beach Pier and the camera systems in the BOQ at the Point Loma Subase. The results are used to validate models for profiles of temperature and humidity over water in the inhomogeneous atmosphere in off-shore flow, and in the presence of waves in on-shore flow. In the analysis, data will be used from buoys along the propagation path, made available by other groups. Also, an effort was made to use a small boat equipped with meteorological instrumentation and an IR sources, to determine the range dependence of the turbulence and refractivity effects.

WORK COMPLETED

During FY97, TNO-FEL has participated in all four EOPACE experiments: IOP4 (San Diego, November 1996), IOP5 (La Jolla, March 1997), IOP6 (Point Sur, April 1997) and IOP7 (San Diego, September 1997). During IOP4, measurements of transmission (broad band, MW and LW) and scintillation were made across San Diego Bay, between the Pt Loma Subase BOQ and Imperial Beach Pier. At both ends of the transmission path a meteorological station was used to measure wind speed and wind direction, air temperature, relative humidity, atmospheric pressure and solar radiation. Particle size distributions were measured on Imperial Beach Pier. Similar measurements were carried out during IOP7, however with a much more extensive series of tests to characterise the propagation environment, including measurements along different propagation paths at different heights. Also a source on a boat was tracked during various occasions. In addition, an effort was made to intercompare the TNO-FEL transmissometer system with the NRaD system, mounted side-by-side at the end of IOP7.

During IOP5, size distributions of surf aerosols were measured with optical particle counters mounted at different heights at the landward side of the surf zone, and with Rotorod impaction samplers particle size distribution profiles were measured at various positions over the surf and outside the surf zone. A sonic anemometer was used to obtain information on the turbulent air flow over the surf . Air temperature and relative humidity were measured at different heights, and meteorological parameters (e.g., wind speed and wind direction) were recorded.

IOP6 was an air mass characterisation experiment in which TNO-FEL participated with a mini-lidar system (wavelength 1.06 μm) mounted on the RV Pt Sur to determine the vertical extent of the aerosol and aerosol backscatter/extinction profiles. TNO-FEL closely cooperated with the Naval Postgraduate School in the aerosol retrieval from AVHRR and the interpretation of the results.

RESULTS

The analysis of the experimental data from the surf aerosol characterisation experiments in both San Diego and Monterey has almost been completed. The aerosol concentrations over the surf are enhanced by one to two orders of magnitude, depending on droplet size, and on ambient parameters such as the surf width and intensity. Clearly, also a dependence on wind speed has been observed, but it remains to be determined whether this is due to generation or a transport issue. The vertical extension of the surf-produced aerosol is on the order of 30 m. A simple line source model has been applied to calculate the horizontal extent of the influence of the surf produced aerosol, in an off-shore wind as during the EOPACE experiments and with the source intensity as determined from the experimental data. Also, a simple model was applied to determine the impact on electro-optical systems. Preliminary results were presented during two conferences [De Leeuw et al. 1997a, 1997b]. Contacts have been made with oceanographers to quantitatively model the surf and its effect on the aerosol production, and with transport modelers to assess the horizontal transport of the surf-produced aerosol and its effect on the aerosol distribution off-shore.

The transmission measurements in Monterey and San Diego have been described in reports by De Jong and Fritz [1996, 1997]. Strong fluctuations were observed that cannot be explained by current models. Refractivity is speculated to be important in this respect. Calculations with state of the art models (e.g. IRBLEM [Van Eijk et al., 1995]) are needed to understand the observed phenomena. Scintillation has also been measured with thermal imagers and a point source at the far end of the propagation path. Preliminary results were presented during the SPIE conference in San Diego.

An initial analysis of the air mass characterisation experiment has been presented in close cooperation with other EOPACE participants [De Leeuw et al., 1997]. A quantitative comparison between aerosol optical depth retrieved from AVHRR images, lidar extinction profiles and aerosol extinction is in preparation [Wash et al. 1997]. To this end, lidar profiles have been processed and will be exchanged.

IMPACT

The results can be used to assess the effects of the atmosphere on the performance of thermal imagers over sea, and in particular the performance of LR-IRST systems.

RELATED PROJECTS

The EOPACE results of TNO-FEL will be exchanged with other EOPACE participants, to lead to a common analysis effort combining all required expertise to achieve the EOPACE goals. The efforts described above are in conjunction with other projects addressing electro-optical propagation over sea, in part basic research, in part applied research. The EOPACE efforts will take place in conjunction with EOPACE efforts funded by the Netherlands Ministry of Defence, including work on long-range transmission, IRST and backgrounds. The laboratory experiments in Luminy are embedded in a EU-supported project on the effect of bubbles on air-sea gas exchange. Data from other areas, e.g. the

North Sea, the North Atlantic, the Mediterranean and the Baltic, are from other projects supported by the Netherlands Ministry of Defence, the EU or other funding agencies.

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